

A FAST SIMULATOR FOR THE SKY MAP OBSERVED BY THE GLAST EXPERIMENT

CLAUDIA CECCHI ^{a,b 1}, FRANCESCA MARCUCCI ^{a,b}
MONICA PEPE ^b GINO TOSTI ^{a,b}

^a *Dipartimento di Fisica, Univ. di Perugia, P.zza dell'Università 1, 06100 Perugia, Italy*

^b *INFN, Sezione di Perugia, via A. Pascoli, 06100 Perugia, Italy*

Abstract

In this report, the implementation of a program for the simulation of the sky map, in the gamma rays energy range, observed by the GLAST experiment will be described. The program generates a list of photons and images of the galactic and extragalactic background and of the sources, in a selected energy range and in a given region of the sky.

1 Introduction

The simulation program is organized as follows: the galactic background map can be generated using the GALPROP program [1] or the model of the diffuse galactic background [2] obtained using observations from EGRET. The extragalactic contribution is given by a constant value in a fixed energy range. The gamma emission of the sources is parameterised using a standard power law and sources from the Third Egret Catalog [3] and faint sources generated following the Stecker and Salamon model [4] are considered. All the contributions (background and sources) are integrated in the given energy range ($[E_{min}, E_{max}]$), in a fixed region ($\Delta b \times \Delta l$) of latitude and longitude and convoluted with the instrumental point spread function (PSF), effective area (SA) and energy resolution (ED) of the LAT instrument [5]. Finally the total intensity is multiplied by the exposure time.

2 Background Description

For the Gamma Ray Galactic Background either GALPROP program or the EGRET model can be used. GALPROP is a simulation program based on a model which reproduces many kinds of observational data related to cosmic-ray origin and propagation. This model provides a good basis for studies of galactic gamma-ray background taking into account the contributions from the most important emission mechanisms. The other possibility is to use the EGRET map

¹claudia.cecchi@pg.infn.it

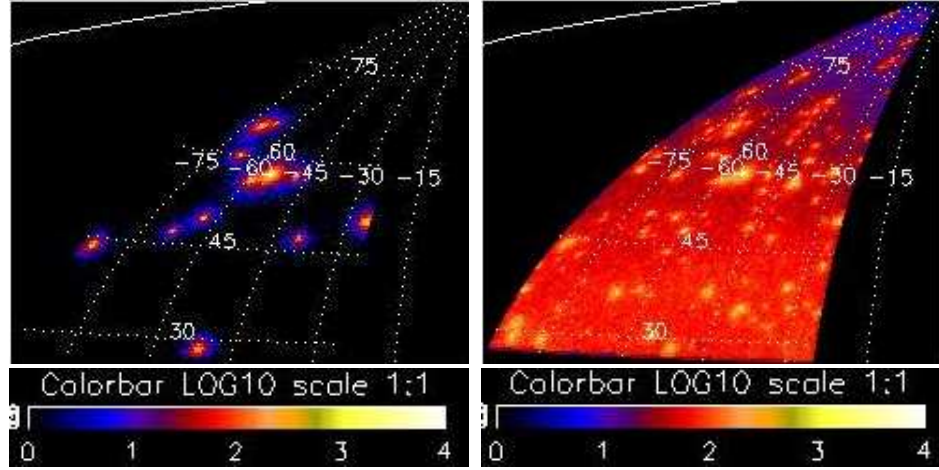


Figure 1: Contribution to the photon flux in the region centred on 3C279 after one precession period in the energy range $0.1 \div 30 \text{ GeV}$. Left: sources only. Right: background plus sources. The colour bar indicates the number of counts.

measured in the energy range between 0.1 and 30 GeV. The diffuse extra galactic background can be described using the differential flux of photons [6]:

$$\frac{dN}{dE} = 7.3 \cdot 10^{-6} \cdot 0.451^{2.1} \cdot E^{2.1} (\text{photons} \cdot \text{cm}^{-2} \cdot \text{s}^{-1} \cdot \text{GeV}^{-1} \cdot \text{sr}^{-1}) \quad (1)$$

The total contribution of the extra galactic background is obtained by integrating Equation 1 between E_{min} and E_{max} .

3 Detector Simulation

The Effective Area (SA), Point Spread Function (PSF) and Energy Resolution (ED) of the detector are energy dependent, the dependence of the effective area on the energy E and on the photon incidence angle θ can be parameterised as: $SA(\theta, E) = SA1(E) \cdot SA2(\theta)$. For a position at $\theta \neq 0$ there is, as a first approximation, also a dependence of the effective area on the angle. The PSF can be described using two different functions: in the simplest case the PSF (for normal incident gammas) is assumed to be Gaussian. The radius containing the 68% of the photons is taken as the RMS of the PSF distribution. As a first approximation we assume that σ_{PSF} is independent on the incidence angle of the photons, but this hypothesis does not take into account that most of the exposure comes from fairly far off axis, where the PSF is broader. A better approximation is to consider a superposition of two Gaussians. Even if this choice underestimates the broad tails, it takes into account both the narrow core and the broad component of the PSF. The energy spread function is also assumed to be Gaussian and, as a first approximation, independent on the inclination.

4 Orbit and Exposure Time Simulation

The duration of the exposure can be either fixed, or calculated using an orbit simulator. The orbit is simulated with a geometrical approach. Orbital parameters, satellite positions and zenith pointing directions are evaluated in steps of 30 s ($\sim 2^\circ$) and assuming that within each step the orbit parameters are constant. The total exposure is calculated adding the contributions over all the steps.

If the total observation time t is not fixed, the exposure \mathcal{E} is computed for each point of the sky in a given region $\mathcal{A}(\Delta b \times \Delta l)$ simulating the orbit of the spacecraft (SC). The exposure will be zero if the SC is in the South Atlantic Anomaly (SAA) or if the angle between the zenith direction and the source is greater than 105° . Outside these regions it will be the product of the exposure time by the effective area SA at energy E. If the time interval t is fixed, the exposure is $\mathcal{E}(E, \theta) = SA(E, \theta) \cdot t$.

5 Convolution with PSF, SA and ED

The differential flux $\mathcal{C}(P_0)$ (photons per unit of area, time and solid angle), is given by the sum of all the contributions: the constant extragalactic background, the galactic one and the sources. The output is a map of the sky that at this stage does not yet include detector resolution effects, in order to have the real image observed by the LAT experiment, we have to convolute our result with the SA, PSF and ED. We define a distribution of the photons as function of the energy given by $D(E) = \int_0^{\theta_{max}} \mathcal{E}(E, \theta) \cdot I(E) d\theta$. The flux $I(E)$ is calculated from:

$$I(E) = I_0 \cdot E^{-\alpha} \text{ (photons} \cdot \text{cm}^{-2} \cdot \text{s}^{-1} \cdot \text{GeV}^{-1}) \quad (2)$$

where I is the flux intensity, E is the photon energy, I_0 is a constant taken from the Egret Catalog and α is the spectral index, assumed to be equal to 2.1 for the background. The total number N' of photons is obtained by integrating the function $D(E)$ between E_{min} and E_{max} : the generated number of photons is then selected assuming a Poissonian statistics. The N photons detected are distributed inside the sky region assigning to them a random energy E_{true} according to the $D(E)$ distribution and an inclination angle distributed according to the function $\mathcal{E}(E_{true}, \theta)$. Then the energy measured by the detector, (E_{meas}) , is obtained using the function $ED(E_{true}, E_{meas})$ and the angular distance, ρ , from the origin point $P_0 = (l_0, b_0)$ consistent with the $PSF(\rho, E_{true})$. The arrival time of the photons is generated taking into account the Poissonian nature of the process and the LAT dead time (assumed to be $100\mu\text{s}$).

As a first approximation the sources are assumed to be point-like, located at an infinite distance and emitting an intensity of photons described by Equation 2. Faint sources can be considered generating their flux F (for $E > 100 \text{ MeV}$) in the range between $10^{10} \text{photons} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ (GLAST lower limit) and $10^{-7} \text{photons} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ (EGRET lower limit) according to:

$$N = N_0 \cdot F^\alpha \quad (3)$$

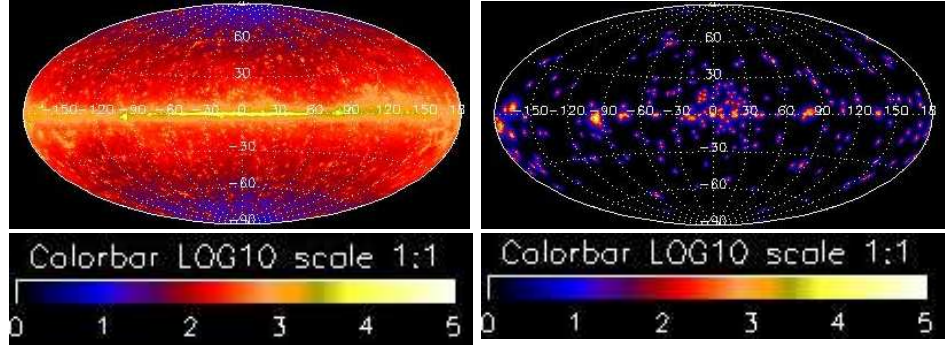


Figure 2: Total number of photons, in a logarithmic scale, from sources (right) and background plus sources (left) after one precession period in the energy range $0.1 \div 30 \text{ GeV}$.

where N is the number of sources with flux F , and N_0 and α are extrapolated using the predicted distribution from Stecker and Salamon. In the case of faint sources the spectral index in Equation 2 is generated according to a Gaussian distribution centred in 2.1 with an RMS equal to 0.2 (classic range for Blazar spectral index). The total number of sources is obtained integrating Equation 3 over the flux range and weighting for the observed fraction of solid angle. The total number of photons from a source is calculated from Equation 2 and they are distributed in the map following the same procedure as described above for the background. In Figure 1 the map with the contribution from the sources and background, is shown, while Figure 2 shows a simulation of the whole sky.

6 Results and Conclusions

The result of the simulation yields images and two tables containing the information required for the analysis. Parameters like the position of the sun and moon have been derived using astrophysical routines which calculates the position of the planets in the solar system knowing the Julian date; while the geomagnetic coordinates have been computed using the GEOPACK [7] code. The output is produced at different stages of the simulation, where the time step is given as input parameter.

A simulation program to calculate the flux of photons observed by the GLAST experiment has been implemented. Contribution from the galactic, extra-galactic background and sources has been included. The effect of the detector is included by convoluting the obtained fluxes with the Point Spread Function (PSF), Effective Area (SA) and Energy Resolution (ED). The time is given either as parameter or it is calculated from the simulation of the orbit.

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